Distributed Engine Control Session

Propulsion Control and Diagnostics Workshop
September 16-17, 2015

Cleveland, Ohio

Session Agenda

3:20 pm **Overview of Distributed Engine Control Development**

– Dennis Culley

3:40 pm **DECWG®: Industry Collaboration & Perspective**

– Bruce Wood, DECWG Chairman

4:10 pm **Modeling & Simulation of Distributed Systems**

– Jonathan Kratz

4:35 pm **Real Time Systems and the Impact of Network Communication**

– Eliot Aretskin-Hariton

5:00 pm **Control Technology and the Impact of the Smart Node**

– Norm Prokop

5:15 pm **Long Term Perspective for Engine Embedded Electronics**

– Glenn Beheim

5:30 pm **Poster Session**

Distributed Engine Control Overview

Dennis Culley

DEC Session Outline

- Motivation in a Heilmeier Framework
- The Scope of the Technology Effort
- NASA Technology Development
  - Modeling
    - Distributed Elements
    - Network Communication
  - Simulation of Distributed Systems
  - Hardware
    - Embedded Nodes
    - Extending Temperature Capability

Distributed Engine Control

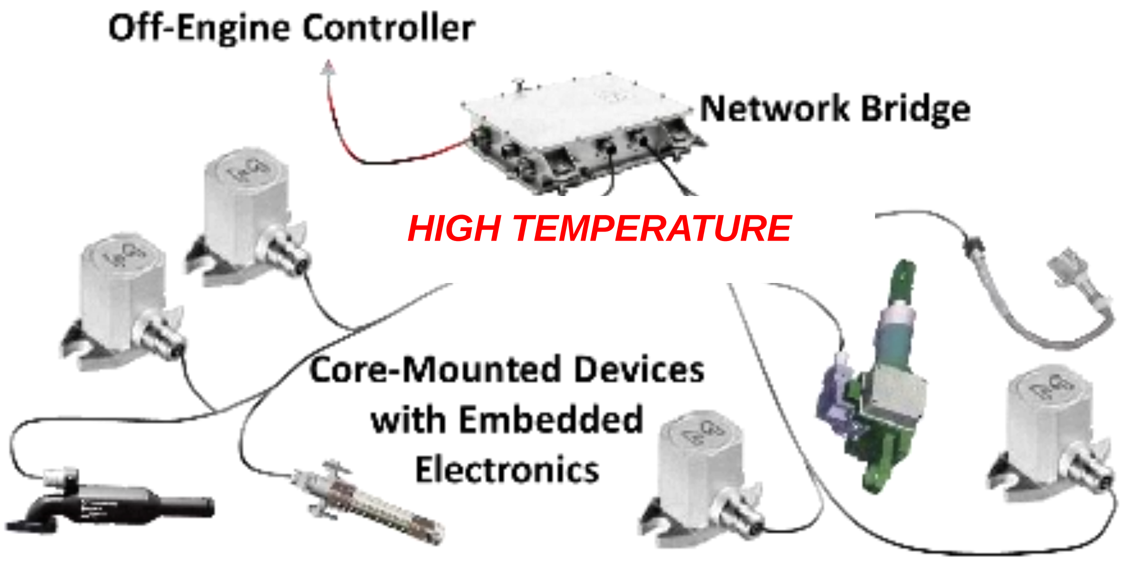
PROBLEM

The interaction between control hardware and the engine thermo-mechanical systems impose constraints that can limit the full realization of new engine technologies.

OBJECTIVE

Extend and quantify the contributions to engine system performance through:

- improving the quality of data,
- the level of system knowledge, and
- the accuracy, responsiveness, efficiency, and safety of the system.



Distributed Engine Control

SIGNIFICANCE

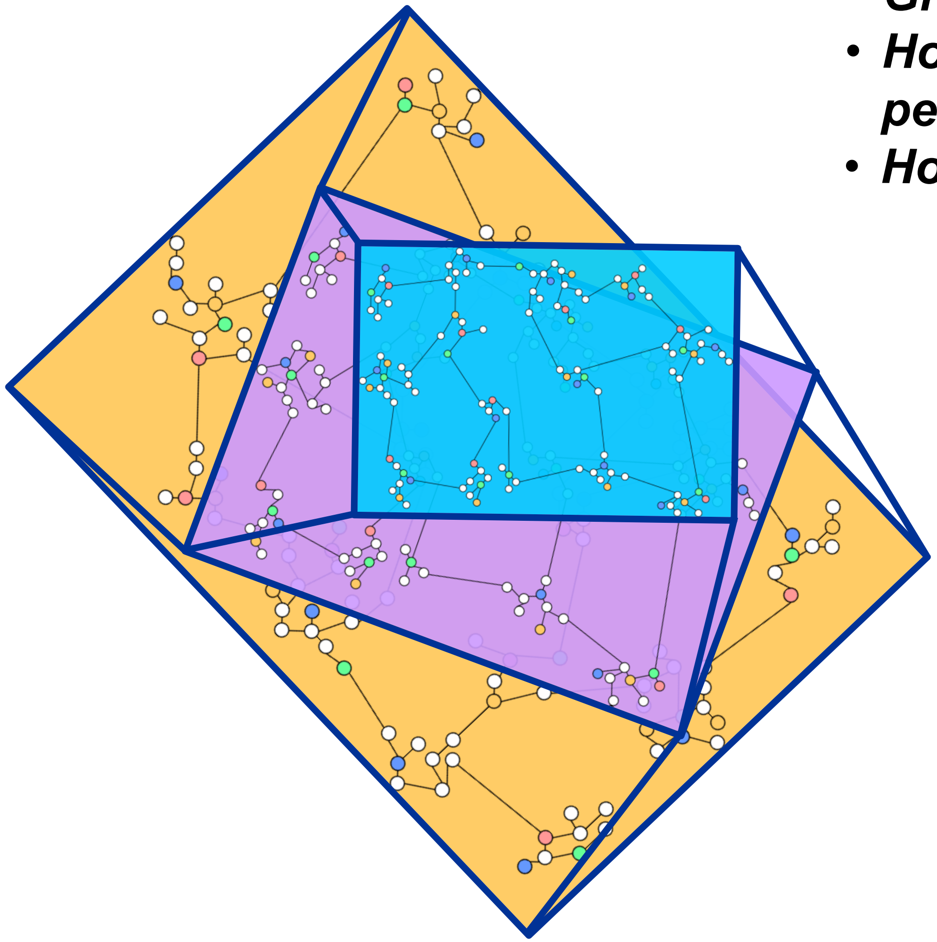
- *Direct reduction of harness weight and reliability*
- *Improves sensor and actuator capability through local embedded electronics*
- *Simplified controller interface allows complex hardware to be located in a more benign environment*
- *Offloads the controller function, enabling more resources for processing intensive capability like data mining and model based control*
- *Growth path for new control technologies.*

Controls is about improving the knowledge of the system and being responsive to its transient operation. This reduces the need to maintain mechanical design margin, potentially leading to higher engine system performance.

Projected Benefits of Distributed Engine Control

	System / Controller	Local / Embedded	Significance / Impact
Fuel Burn	more resources for multivariable control	enables more responsive smart actuation	reduced fuel burn / constant thrust increased thrust / constant fuel burn
Emissions	more resources for multivariable control	enabler for local active control technology	new technology potential
Acoustic Noise	more resources for multivariable control	enabler for local active control technology	new technology potential
Weight	reduced harness weight		lower system weight
Volume	increased flexibility in mounting controller		lower nacell drag
	multiple modular LRUs		lower profile core, optimized use of space, simplified maintenance
Availability	improved fault detection, isolation, mitigation, and repair		improved time in service, mission success
Reliability	reduced In Flight Shut Down, Unexpected Repairs		
Cost	reuse of modular controls		reduced development cost reduced production cost
	reduced impact of obsolescence, reduced impact of upgrade		reduced sustanment cost
External Threats	improved electromagnetic susceptibility cybersecurity		increased immunity to external threats
Thermal Management	avoid high temperature	accommodate high temperature	reduced need for cooling systems

Engine Control Eco-System



NASA Controls Technology

- *Growth*
- *How do we use the technology to enhance performance, operability, & safety?*
- *How do you sustain the Eco-System?*

DECWG® Precompetitive Technology

- *Collaboration*
- *Common barriers*
- *The common "materials" for controls*

Engine Control System Technology

- *Differentiation*
- *Closely held intellectual property*

DEC Modeling & Simulation

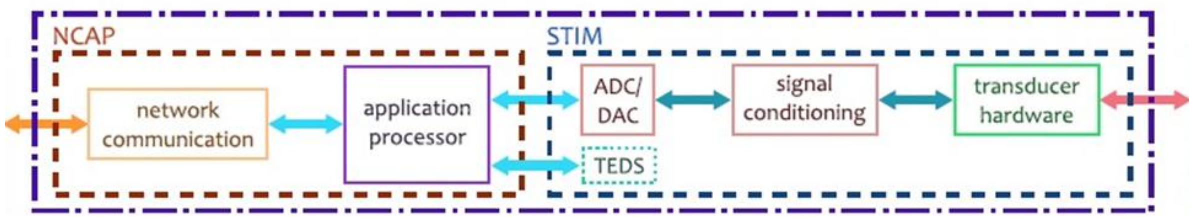
PROBLEM

Distributed control is characterized as a system of asynchronous systems, thus it is fundamentally different from that of the centralized FADEC control architecture now used in aero-engines. A deep understanding of this structure is necessary for the design, analysis, and verification of future modular control architectures.

SIGNIFICANCE

The creation of modeling and simulation tools supporting a modular structure and common interfaces contributes to a collaborative environment for controls development from concept through hardware development. This recognizes that extended participation of the supply chain will be necessary in future requirements development.

NCAP – Network Capable Application Processor
STIM – Smart Transducer Interface Module



Smart Sensor Model

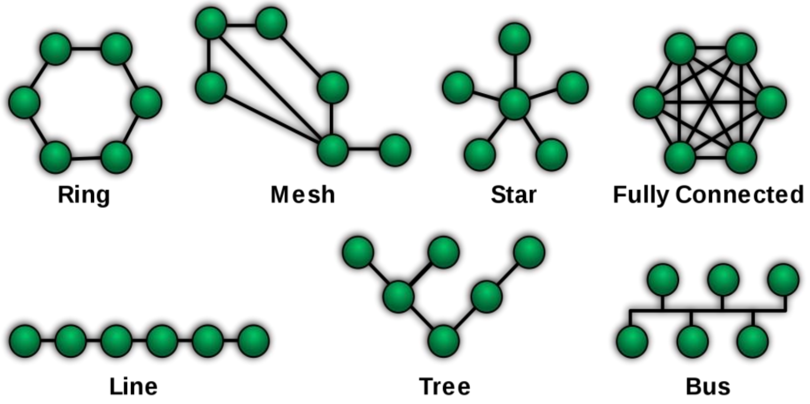
DEC Communication Modeling

PROBLEM

Distributed control requires control elements to communicate serially over digital networks, thus affecting the flow of information available to the controller. But the engine environment also constrains the performance of underlying hardware. These effects coupled with new fault modes, are not well understood.

SIGNIFICANCE

Communication networks are fundamental to the integration and performance of distributed control systems. The complexity of testing systems is significantly increased by the potential for large numbers of attached hardware elements. These tools will make a major impact by reducing design time and simplifying system integration.



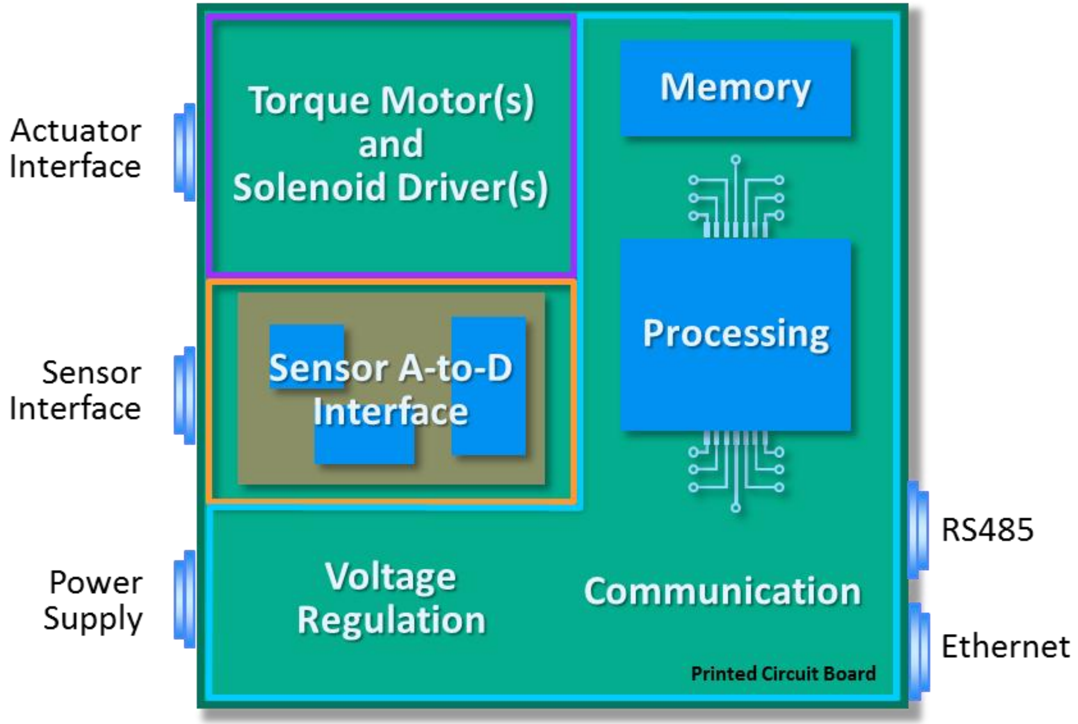
DEC High Temperature Node Capability

PROBLEM

High temperature electronics have very limited available component selection. Also, to achieve high reliability some component de-rating (relative to consumer equivalent components) is necessary.

SIGNIFICANCE

The processing power and capability of embedded electronics on/near the engine casing directly affects the available control functionality. Understanding this new potential, and the applications for local loop-closure, directly determines the complexity and potential for new performance-enhancing engine control.



DEC 500ºC Silicon Carbide (SiC) Electronics

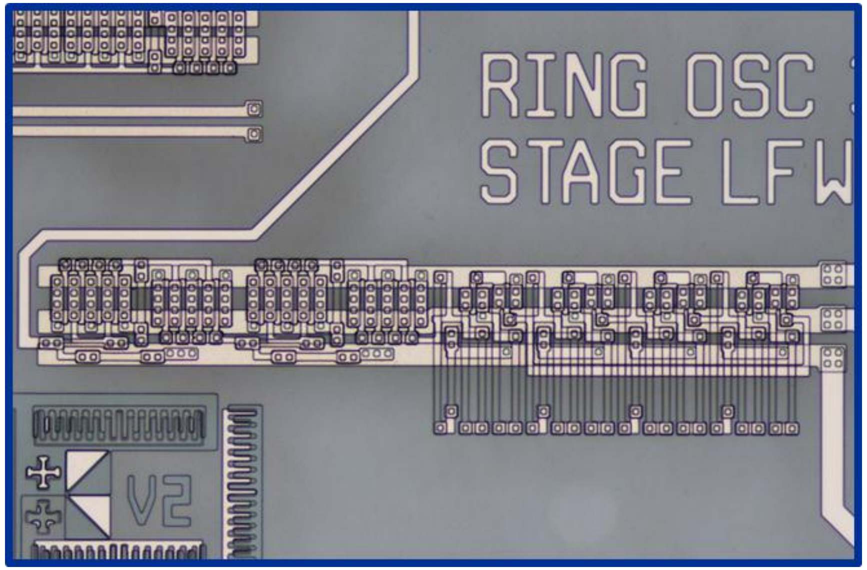
PROBLEM

In the near term, smart embedded devices utilizing high temperature electronics technology are limited to operating environments with temperatures less than 300°C.

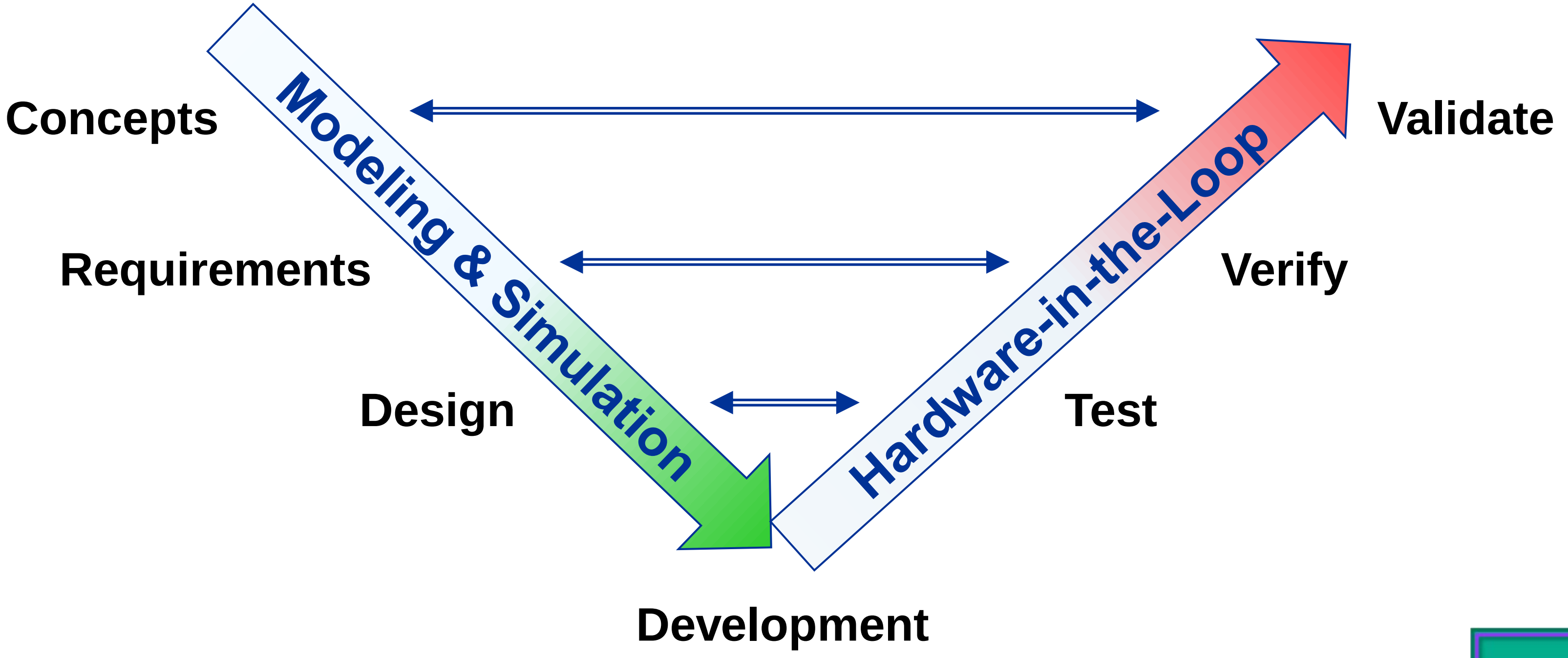
SIGNIFICANCE

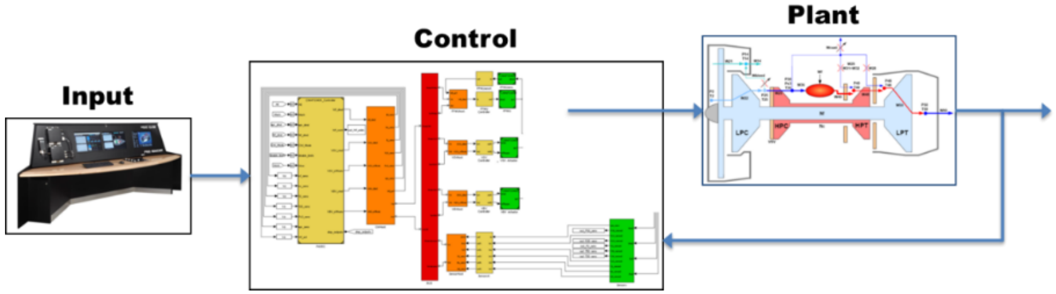
High density, high temperature (>300ºC) SiC based electronics will enable/extend control capabilities for the turbine engine:

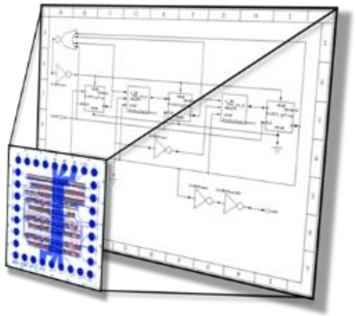
- *Improve the accuracy of existing sensors*
- *Increase the information that can be extracted from the engine system*
- *Provide local processing capability to reduce the computational burden on controllers*
- *Improve the reliability and safety of the engine system*

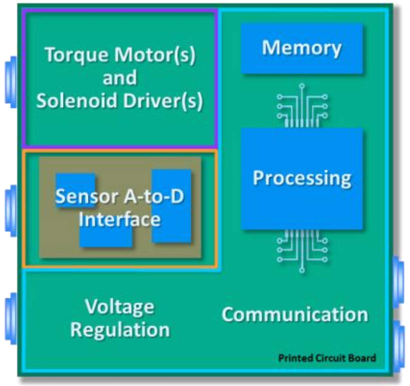


Innovating Higher Performance for Turbine Engines



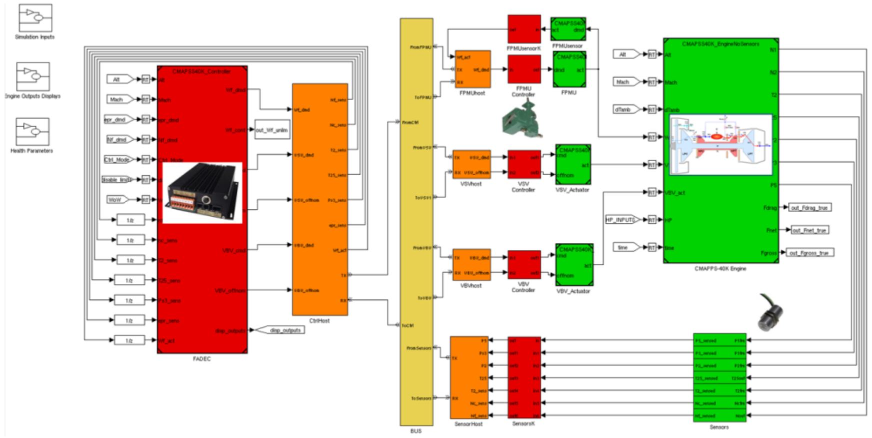






Distributed Engine Control Technologies

Modeling – Simulation – Hardware-in-the-Loop

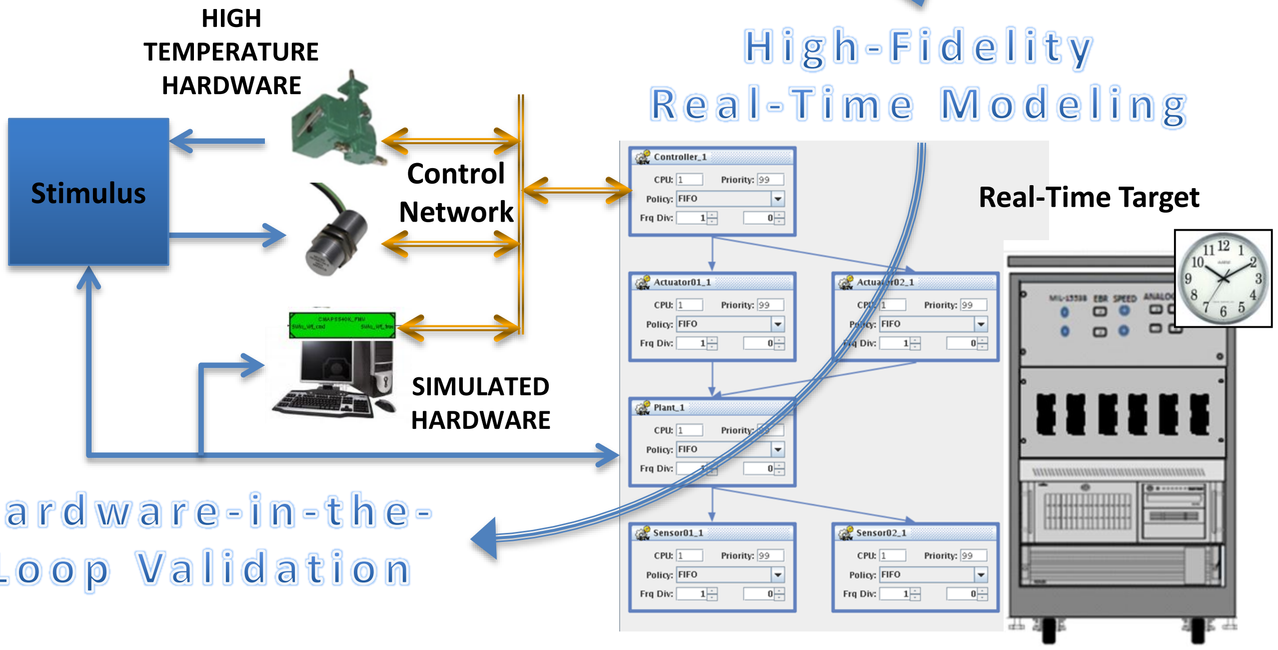


Collaborative Simulation Environment for SBIR and component suppliers to develop new technology concepts

Concept

High-Fidelity Real-Time Modeling

Collaborative Hardware Environment to verify high temperature technologies developed by DECWG, especially related to “system of asynchronous systems” integration



Hardware-in-the-Loop Validation

Summary

- Distributed Engine Control is a technology made necessary by constraints imposed by the engine system.
- High temperature electronics is the primary barrier to implementing distributed control technology. It is also a cost barrier that drove the formation of the DECWG™ consortium.
- DECWG is necessary for sustaining the engine control eco-system.
- Embedded high temperature nodes on the engine present an opportunity to:
  - Increase the computational resources for performance-enhancing control and propulsion health monitoring
  - Provide a feasible method to implement high bandwidth local control
- Unknowns with high temperature electronics require modeling tools to quantify control requirements and system performance benefits.
- Integration of distributed systems requires network modeling capabilities.
- Advancing the capability of high temperature electronics provides a long term growth path for engine control technology and higher performing engine systems.